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**(54) Title:** ERADICATION OF MARKS AND STAINS BY LASER

**(57) Abstract**

A method of and apparatus is described for eradicating marks and stains at or beneath the surface of a substrate. The technique involves the use of a variable wavelength pulsed laser and an optical fibre delivery system to direct a spot of laser light at the treatment site. The laser produces an output in the form of a pulse having a duration in the range of 0.1 to 100 microseconds, at an energy level in the range of 0.5 to 5 Joules at a wavelength in the range of 400 to 900 nanometres. The output may consist of a single pulse or a sequence of pulses with a repetition rate selectable from 1 to 20 Hz. Marks in many different material may be eradicated using this technique. Examples are leather, wood, plastics and skin lesions such as tattoos and "port wine stains".

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## ERADICATION OF MARKS AND STAINS BY LASER

THIS INVENTION concerns a method of and apparatus for eradicating marks and stains by laser and is particularly though not exclusively concerned with removal of pigmentation at or beneath the surface of a substrate.

Applications of the method are manifold, such as removal of marks and stains in hides or made up articles of leather, from wood especially in articles of furniture, from textiles and articles of clothing, and any application where pigmented or other marks or stains require elimination without damage to the surrounding substrate. A further example is the removal of skin lesions including pigmented lesions such as tattoo marks, moles, etc, and vascular lesions such as "port wine" stains.

Attempts have been made to remove pigmented marks using a Q-switched ruby laser. Such a laser generates a very short pulse duration in the region of 10 to 30 nano seconds and imposes power densities on the substrate in the region of 1,200 to 2,800  $\text{GW m}^{-2}$ . Such power densities may cause damage to the surrounding substrate. Furthermore, a Q-switched ruby laser cannot deliver its treatment beam to the site using a flexible optical fibre. This is due to the very high power densities generated, and an articulated arm must be used for delivery.

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Additionally, ruby lasers operate on a single wavelength system, usually 693 nanometres.

An object of the present invention is to provide a method of and apparatus for the eradication of marks and stains, using a tunable laser which is effective in removal whilst operating at power densities far less than that generated by a Q-switched ruby laser, and with longer pulse duration, and wherein a flexible optical fibre may be used to deliver the treatment beam to the site.

According to the present invention there is provided a method of eradicating marks and stains at or beneath the surface of a substrate, comprising the step of directing at said surface, laser light generated by a variable wavelength pulsed laser, the laser operating to produce an output in the form of a pulse having a duration in the range of 0.1 to 100 microseconds, at an energy level in the range of 0.5 to 5 Joules, and at a wavelength in the range of 400 to 900 nanometres.

In a preferred method the laser produces a sequence of pulses with a repetition rate in the range of 1 to 20Hz.

Still further, the laser energy is preferably delivered to the surface via a single or multiple core optical fibre having a core size in the range of 600 to 1500 $\mu$ m.

In this way, the fibre optic delivery system may be hand-held allowing for the adjustment of the spot size of the laser beam

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on the surface, so that it can be selected within the range of 1 to 100mm in diameter.

The basic principle behind the method is that the laser is used to irradiate the site of the mark or stain in the substrate, and the wavelength at which the laser operates is chosen so that the mark or stain absorbs the radiation whilst unmarked surrounding substrate absorbs only little and so is not damaged. In this way a selective effect is obtained.

Further according to the present invention there is provided a pulsed laser apparatus for eradicating marks and stains at or beneath the surface of a substrate, the apparatus comprising a variable wavelength pulsed laser which is tunable to produce an output in the form of a pulse having a duration in the range of 0.1 to 100 microseconds, at an energy level in the range of 0.5 to 5 Joules, and at a wavelength in the range of 400 to 900 nanometres.

The apparatus comprises a fibre optic delivery system incorporating an optical fibre having a core size in the range 600 to 1500 $\mu$ m.

It is believed that the aforesaid method may be effected in many different applications such as the removal of pigmentation marks and stains at or beneath a translucent surface and also for creation of marks, for example, on self-coloured plastics material by removing pigmentation preferentially in selected areas thus to produce

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identification marks. One example of such application is an electrical cable having self-coloured sheathing which, by the application by the laser light in accordance with the invention may be selectively marked.

Coloured substrates may have a pattern or printing imposed thereon, by selective eradication of pigmentation. These effects may be established at and/or just beneath the surface of the substrate thus to be visible thereat.

An embodiment of the method in accordance with the invention will now be described in relation to the removal or reduction of skin lesions such as tattoo marks and port wine stains.

A tattoo mark is produced by a dark pigment (usually blue or black) introduced into the dermis. The particles of pigment are not removed by normal cellular activity and so the mark is permanent. The colour particles which make up the tattoo usually absorb well at wavelengths in the red part of the spectrum corresponding to a wavelength in the range of 650 to 700nanometres. However, these wavelengths are not absorbed by normal unmarked skin and so are scattered such that the energy is dissipated over a relatively large area with little or no effect on normal tissue.

In the lesion itself the radiation is very efficiently absorbed and so the energy is concentrated in or around the pigmented area.

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The design of the laser system is such as to increase the discrimination between tissue which forms part of the lesion, and normal unmarked tissue. For example, pulsed energy is important. A pulse of energy is deposited in the effected tissue for a time which is short when compared with the thermal relaxation time of the tissue. This means that the heat is generated locally and will not significantly spread by conduction to other, non-pigmented tissue. Thus, thermal injury to the adjacent tissue is avoided. This is an important aspect of the present invention for use on skin lesions, in contact with methods which use continuous wave lasers (including carbon dioxide and argon lasers) producing a much higher degree of thermal injury to the surrounding tissue. Furthermore, pulsed radiation generates an acoustic shock wave at the treatment site, which generally improves the effectiveness of the treatment. This appears to be due to the breakup of pigmented particles into smaller pieces which can then be removed by normal cellular activity. To generate a shock wave the pulse must be of a duration in the range of 0.1 to 100 microseconds, with an optimum duration of between 1 and 5 microseconds.

A tunable or variable wavelength laser may be used to treat skin lesions in several different ways. For example, for complete removal within one or two treatment sessions, the area treated should be in the region of 1 to 3mm in diameter, per pulse. However, the consequent high energy density results in selective thermal injury and there would be some scarring, but this will heal well and is not extensive. This process compares most favourably

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with existing practice using, for example, carbon dioxide lasers where there is no tissue selectivity and where removal of a large area of tissue is required with significant thermal injury and scarring. In effect, when laser apparatus is used in accordance with the invention it requires much less operator skill since it is less likely to produce accidental or co-lateral thermal damage when compared with existing processes.

In alternative eradication mode a spot size of 3 to 5mm may be treated requiring 3 to 4 sessions for each irradiated area. Consequently, this results in much less thermal damage but requires a greater number of process sessions.

Again, complete removal of pigmented lesions can be achieved with no residual scarring at all, but in this case some 5 to 7 process sessions on a larger site would be required, resulting in gradual fading of the lesion.

When the process is applied to the eradication of vascular lesions such as "port wine stains", the pulse duration must be selected in the range of 20 to 100 microseconds, whilst the wavelength should be in the region of 500 to 600 nanometres.

Selection of the operating parameters of the laser within the scope of the invention as aforesaid may be made according to the nature of the mark or stain to be removed, and of the substrate material.

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The laser may be either a flash tube excited laser or a tunable solid state laser such as a titanium sapphire laser.

It is envisaged that the operating ranges of the laser may be selected automatically by a control function which responds to a selection of a mark/substrate type. In this way, semi-skilled or perhaps even unskilled technicians may be capable of eradicating marks and stains effectively.

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### CLAIMS

1. A method of eradicating marks and stains at or beneath the surface of the substrate, comprising the step of directing at said surface, laser light generated by a variable wavelength pulsed laser, the laser operating to produce an output in the form of a pulse having a duration in the range of 0.1 to 100 microseconds, at an energy level in the range of 0.5 to 5 Joules, and at a wavelength in the range of 400 to 900 nanometres.
2. A method according to Claim 1, wherein said pulse duration is in the range of 0.1 to 20 microseconds.
3. A method according to Claim 1, wherein said pulse duration is in the range of 20 to 100 microseconds.
4. A method according to Claim 1 or Claim 2, wherein said pulse wavelength is in the range of 400 to 800 nanometres.
5. A method according to Claim 1 or Claim 3, wherein said pulse wavelength is in the range of 500 to 600 nanometres.
6. A method according to any preceding claim, wherein the laser output consists of a sequence of pulses with a repetition rate selectable in the range of 1 to 20Hz.
7. A method according to any preceding claim, wherein the laser energy is delivered to the substrate surface via an optical fibre

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having a core size in the range of 600 to 1500 $\mu$ m.

8. Apparatus for eradicating marks and stains at or beneath the surface of a substrate, comprising a variable wavelength pulsed laser adapted to produce an output in the form of a pulse having a duration in the range of 0.1 to 100 microseconds, at an energy level in the range of 0.5 to 5 Joules, and at a wavelength in the range of 400 to 900 nanometres.

9. Apparatus according to Claim 8, wherein said pulse duration is in the range of 0.1 to 20 microseconds.

10. Apparatus according to Claim 8, wherein said laser is adapted to produce a pulse of duration in the range of 20 to 100 microseconds.

11. Apparatus according to Claim 8 or Claim 9, wherein said laser is adapted to produce a pulse of wavelength in the range of 400 to 800 nanometres.

12. Apparatus according to Claim 8 or Claim 10, wherein said laser is adapted to produce a pulse of wavelength in the range of 500 to 600 nanometres.

13. Apparatus according to Claim 8, in which said laser is adapted to produce a sequence of pulses at a repetition rate selectable from 1 to 20Hz.

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14. Apparatus according to any one of Claims 8 to 13, including an optical fibre connected to the output of the laser for delivery of said laser light, and having a core size in the range of 600 to 1500 $\mu$ m.

15. A method of eradicating skin lesions including pigmented lesions such as tattoo marks, moles, etc. and vascular lesions such as "port wine stains", the method comprising the steps of directing at the treatment site, laser light generated by a variable wavelength pulsed laser, the laser operating to produce an output in the form of a pulse having a duration in the range of 0.1 to 100 microseconds, at an energy level in the range of 0.5 to 5 Joules, and at a wavelength in the range of 400 to 900 nanometres.

16. A method according to Claim 15, wherein said pulse duration is in the range of 0.1 to 20 microseconds for removal of pigmented lesions.

17. A method according to Claim 15, wherein said pulse duration is in the range of 20 to 100 microseconds for removal of vascular lesions.

18. A method according to Claim 15 or Claim 16, wherein said pulse wavelength is in the range of 400 to 800 nanometres for pigmented lesions.

19. A method according to Claim 15 or Claim 17, wherein

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said pulse wavelength is in the range of 500 to 600 nanometres for vascular lesions.

20. A method according to Claim 15, wherein said pulse duration is in the range of 1 to 5 microseconds for pigmented lesions.

21. A method according to any one of Claims 15 to 20, wherein the laser energy is delivered to the lesion site via an optical fibre having a core size in the range of 600 to 1500 $\mu$ m.

22. A method according to Claim 21, wherein the optical fibre delivery system is hand-held thus to allow adjustment of the spot size of the laser beam on the lesion site and thus in turn to determine intensity of the energy per pulse generated at the site.

# INTERNATIONAL SEARCH REPORT

International Application No. PCT/GB 92/00739

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>9</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC Int.C1.5 A 61 B 17/36 B 44 C 1/22		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>8</sup>		
Classification System	Classification Symbols	
Int.C1.5	A 61 B B 44 C	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup></b>		
Category <sup>9</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
X	Conference on Lasers and Electro-Optics, Baltimore, Maryland, 21-24 May 1985, OSA/IEEE, M.S. SOBEY et al.: "Flashlamp-pumped dye-laser treatment of port wine stains", article WM46	1,2,4,5 ,7-9,11 ,12,14
Y	---	3,10
Y	US,A,4829262 (H. FURUMOTO) 9 May 1989, see column 1, line 1 - column 6, line 57	3,10
A	---	1,2,4-9 ,13,14
A	EP,A,0377050 (SUMITOMO ELECTRIC INDUSTRIES, LTD) 11 July 1990, see the whole document	1,7,8, 14
	---	-/-
<p><sup>9</sup> Special categories of cited documents :<sup>10</sup></p> <p><sup>"A"</sup> document defining the general state of the art which is not considered to be of particular relevance</p> <p><sup>"E"</sup> earlier document but published on or after the international filing date</p> <p><sup>"L"</sup> document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p><sup>"O"</sup> document referring to an oral disclosure, use, exhibition or other means</p> <p><sup>"P"</sup> document published prior to the international filing date but later than the priority date claimed</p> <p><sup>"T"</sup> later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p><sup>"X"</sup> document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p><sup>"Y"</sup> document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p><sup>"&amp;"</sup> document member of the same patent family</p>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
30-06-1992	24.07.92	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	Maria Peis <i>Maria Peis</i>	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		Relevant to Claim No.
Category	Citation of Document, with indication, where appropriate, of the relevant passages	
A	EP,A,0172490 (MEDICAL LASER RESEARCH AND DEVELOPMENT CORP.) 26 February 1986, see page 1, line 1 - page 6, line 24; page 11, line 9 - page 16, line 3 ---	1-14
A	WO,A,9012545 (DERMALASE LTD) 1 November 1990, see page 2, line 10 - page 8, line 16 ---	1,6,13
A	Physics in Medicine and Biology, vol. 32, no. 12, December 1987, (Bristol, GB), A.R. HENDERSON et al.: "The 'light touch': a dermatology handpiece designed to improve the efficacy and safety of laser treatment of port-wine stains", pages 1627-1630 -----	1,7,8, 14

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/GB92/00739

### Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.: 15 - 22  
because they relate to subject matter not required to be searched by this Authority, namely:  
Please see Rule 39.1(iv) - PCT:  
Method for treatment of the human or animal body by surgery or therapy,  
as well als diagnostic methods.
2.  Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3.  Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

### Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2.  As all searchable claims could be searches without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

#### Remark on Protest

The additional search fees were accompanied by the applicant's protest

No protest accompanied the payment of additional search fees.

ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO.

GB 9200739  
SA 58731

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.  
The members are as contained in the European Patent Office EDP file on 16/07/92.  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A- 4829262	09-05-89	US-A-	5066293	19-11-91
EP-A- 0377050	11-07-90	WO-A-	8912239	14-12-89
EP-A- 0172490	26-02-86	JP-A-	61058673	25-03-86
		US-A-	4733660	29-03-88
WO-A- 9012545	01-11-90	AU-A-	5422490	16-11-90